BTeV Preliminary Commissioning Plan

Executive Summary

This document outlines our plan to commission the C0 IR and the BTeV detector. Commissioning is built into the BTeV design, construction and installation plans in order to minimize the time required so that we can quickly acquire quality data to compete with LHCb, an experiment we assume will have already started data taking.

Many of the items normally considered to be in the commissioning phase of an experiment will be done before or at the time of installation. For example, the trigger and DAQ systems will have already been tested on Monte Carlo input data including beam collisions as well as noise and other backgrounds. BTeV has a unique trigger and data acquisition design that allows rapid commissioning of all the detector elements. All of the sub-detectors use the same DAQ scheme with a common design.

We also intend to have ready all the software needed for alignment, monitoring and other calibrations well before the beam arrives and also to have tested it on Monte Carlo. Our experience has been that having tested software and an effective monitoring system assures a quick and efficient commissioning.

The schedule shown here presents a plan for commissioning the interaction region that will take 14 days before the turn on of beam (when the detector installation is finishing) and 25 days of work with the beam to get interactions at moderate luminosity. Detector commissioning then takes an additional 5 weeks.

1 Introduction

BTeV plans to begin taking physics quality data rapidly after installation is completed, so that its results will be timely, especially since it is competing with another b-physics experiment, LHCb. The purpose of this document is to describe a plan for the very rapid commissioning of the BTeV detector in C0.

The context in which this plan is developed is:

1) The continuing availability of the MTEST test beam at Fermilab;
2) A well-understood Tevatron with peak Luminosity between 1-3x10^{32} beyond 2007;
3) The existing Run 2 schedule, including the scheduled periods from 2006-2008 when the Tevatron is off and installation in C0 will be allowed;

4) The right to install and operate equipment in the C0 Collision Hall and to create collisions, for short time intervals, on both a wire target or with colliding beams at the end of stores during this period;
5) The current BTeV Schedule – here assumed to be the "staged" schedule; with a major installation period of 17 weeks in 2009 for the Stage 1 detector; and a second installation period of up to 13 weeks in July of 2010 for the Stage 2 detector;

To be successful, planning for rapid commissioning has to be taken into account throughout the R&D, design, construction, and installation process. The plan includes an "R&D" phase, a two part "pre-operations" phase, and a "final commissioning" phase.

Rapid commissioning of the detector subsystems is facilitated by operating prototype versions of them under a wide variety of conditions, especially those that will be encountered in normal operation. In the "R&D" phase the "operating parameter space" of each detector will be worked out and verified with beam in MTEST. In the "pre-operations" phase, part 1, each detector will be read out using a prototype of its front end electronics and a prototype of the DAQ. This is a "vertical slice test." Then, the detectors will be read out all together in a "horizontal slice test." Then, sometime in 2007, in the second part of the pre-operations phase, we will move the prototype detectors from MTEST to C0 and install them in the Collision Hall where they can be exposed to particles from collisions in a wire target in the beam halo or from end-of-store proton-antiproton collisions obtained by turning separators off. After the installation period in 2009, final commissioning of the Stage 1 detectors will be accomplished using proton-antiproton collisions. The Stage 2 detectors will be commissioned towards the end of 2010 using proton-antiproton collisions.

In collider experiments, the trigger and data acquisition systems have traditionally taken a long time to commission. The BTeV trigger and data acquisition systems have been designed differently than most recent collider experiments. The data acquisition of all detector elements uses a common scheme. All electronic front ends are multiplexed in data-combiner boards (DCBs) with a common design across all detector elements. The DCBs reside in the Collision Hall, convert data from each detector to serial pulse trains, provide correct timestamps, and send them over optical links to the C0 Counting Room where they go either into Level 1 buffers (L1Bs) or into the trigger system. All data are aligned in time using time stamps provided by the Tevatron crossing clock and the large Tevatron bunch spacing –396 ns – makes time alignment relatively simple. Since all interactions happen synchronously, within a small 10 ns window, no precision timing of any kind is required within this system. The trigger then looks at the digital information from a subset of these detector elements and decides whether or not to keep the data from the crossing. **This unique design facilitates rapid commissioning.**

The trigger is based mostly on commercial computing nodes and commercial network interconnects rather than specifically designed hardware and special cabling relating hits in one part of a detector with those in other parts and hits in one type of detector with hits in another type. In BTeV, all triggers at all levels are performed by calculations in massively parallel computer farms. Events are pipelined through the farm nodes with a variable latency. This makes it possible to write computer algorithms to process the data through the trigger in short enough times to keep up with the full interaction rate. Furthermore the trigger is designed with input buffers that can accept raw data from the detector or simulated "raw data" generated by our GEANT-based Monte Carlo. Software in the simulation permits us to inject faulty data (electronic noise, inefficiencies, beam halo) into the data stream, permitting us to test the trigger on data that is realistic or even worse than that likely to be encountered in the experiment. In fact Monte Carlo has been used extensively in trigger design and will be crucial to expedite the commissioning process.

The downstream part of the DAQ design is also very simple and facilitates advance testing and rapid commissioning. All data from each crossing, identified by its crossing number, is stored in a very large (~1 Tbyte) buffer memory. Data readout consists of transferring the appropriate data fragments for a crossing to a single Level 2/3 computer (a commercial processor running LINUX) and, if the trigger is satisfied, writing it to permanent mass storage. Again, Monte Carlo data can be deposited in the buffer memory and data taking can be simulated in a very realistic manner for advance testing.

Experience with systems in other detectors such as CLEO and FOCUS has shown that it is crucial not only to be able to check out the hardware in advance of data-taking but that it is equally important to develop all the software needed to calibrate the detectors and then perform the calibrations on Monte Carlo data well before data-taking. Such procedures have allowed new subsystems such as the CLEO CsI calorimeter to start taking useful data within days of their exposure to beam. BTeV is developing a detailed plan to have the required software ready and tested well in advance of beam.

2 General Description of Commissioning Plan

Here, we describe each phase of our plan.

2.1 Phase 1: R&D

The R&D phase includes testing of a small-scale prototype of each detector in a test beam, either MTEST at Fermilab or an electron/pion bean at IHEP in Protvino. In this stage, we establish the operating parameter space of each detector, including high voltage settings, choice of gases, and threshold settings. This phase is currently underway.

2.2 Phase 2: Pre-operations

2.2.1 Part 1: MTEST phase

In MTEST, single beam particles will pass through all BTeV Detectors and permit linking and correlation studies. The main activities of this part of phase 2 are:

1. Careful validation of all detector designs in the test beam, including read out of each detector with at least prototype front end and DAQ electronics before the end 2007.
2. Readout and data collection of all prototype detectors in tandem as a single event using a prototype version of the final DA.

This part of phase 2 has many benefits. Alignment techniques can be developed and tested. Online and offline software can be checked out. We leave open the option of using a small magnet and target to study the reconstruction of actual interactions with this setup.

2.2.2 Part 2: C0 phase

After the BTeV Vertex Magnet and compensating dipoles are installed in the C0 Collision Hall, we begin part 2 of the pre-operations phase. We will move the equipment from MTEST to C0 and augment it with the "10% pixel prototype" system, which will be located outside the beam pipe at the C0 Interaction Point. The test includes operation of

1. the BTeV analysis magnet and compensating dipoles
2. the 10% pixel system, located outside the beam pipe, and coupled to at least one highway of the BTeV trigger and DAQ
3. a half-station of the forward trackers, consisting of three half views of straws and three half views of silicon microstrip detectors
4. The RICH test vessels, both gas and liquid radiator, with their final electronics.
5. The test stack of the EMCAL with its final readout
6. One complete octant (4 views) of one muon station

The pre-production front end electronics will receive its clock from the final system. Readout will be through DCBs onto fibers running into the Counting Room. Interactions will be made by collisions of the antiproton beam in a wire target in the beam halo, or by collision of beam protons on antiprotons obtained by with a special set of separator settings at the end of collider stores. This configuration allows us to study the performance of all the detectors, the pixel trigger and DAQ,to debug the clock distribution system and develop time alignment (synchronization) techniques, to continue special alignment and linking studies, and test the clock distribution system.

Accompanying this will be a vigorous program of machine and detector background simulations and a software effort to prepare online and offline calibration, diagnostic, and monitoring programs.

2.3 Phase 3: Pre-installation Checkout and Final Commissioning

2.3.1 Pre-installation checkout

The "final commissioning" phase must be viewed in the context of the checkout and installation plan, since that determines the status of the sub-detectors as the beam becomes available.

Before being installed in C0, either in a special staging location at Fermilab or in the C0 Assembly area itself, each detector will be checked out in its operating configuration. All detectors have preliminary high voltage settings established for operation with sources, cosmic rays, pulsers, or the test beam work of phase 1. All detectors are read out by final front end electronics into a Data Combiner Board (DCB) located near the detector. Once moved into C0, all detectors are again set to their operating conditions and connected to their final DCBs. The DCBs convert data from each detector to serial pulse trains, with correct timestamps, and send them over optical links to the counting room where they go either into Level 1 buffers (L1Bs) or into the trigger system in the C0 Counting Room.

2.3.2 Checkout and Commissioning of the Final Detectors with collisions in C0

This involves commissioning of each detector, the trigger and the data acquisition system with particles from proton- antiproton collisions. It includes doing any studies or calibrations required to get all the detector components to work together to achieve the physics goal of the experiment.

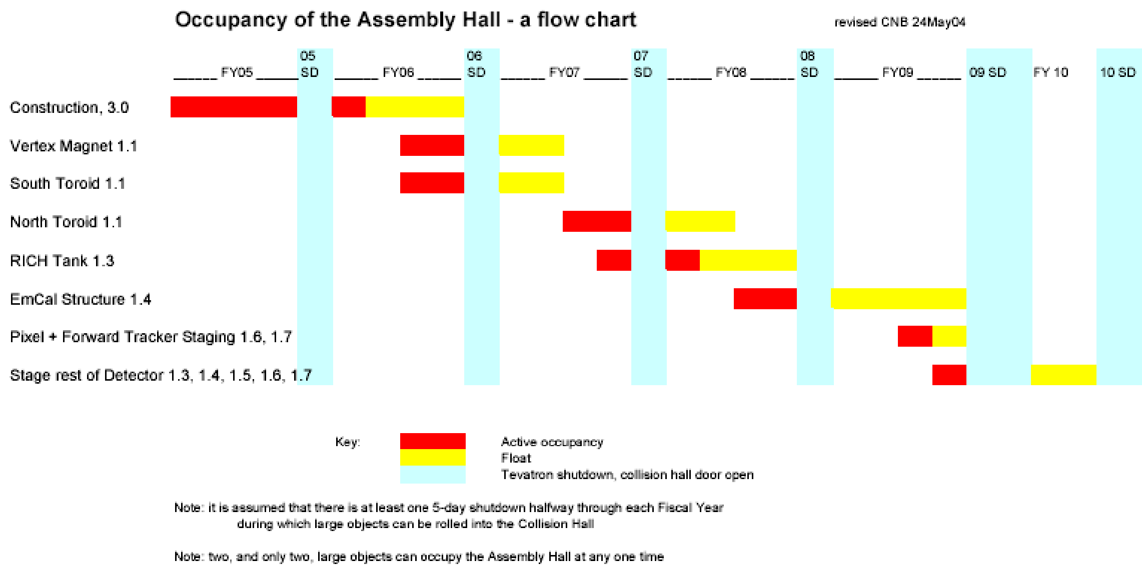
Since detector checkout is performed up to the input of the DCBs and trigger and DAQ checkout is performed by depositing simulated raw data into the buffers of the trigger and DAQ at the very earliest point, we expect the trigger and DAQ system to come up immediately and to be available to support commissioning of the detectors.

A commissioning "run plan" is given in sections 7 and 8 below.

3 Status and Schedule

The first phase of the commissioning plan, the MTEST phase, is underway now. It will give way, in 2005, to part 1 of the pre-operations phase. This phase can last as long as good progress is being made but is expected to wind down in 2006, as effort focuses on activities in C0 starting at some point in 2007.

The schedule for installation of major BTeV components in C0 may be understood from the "occupancy" plan for the C0 Assembly Hall. The end of the red bar shows when it is expected for each device to move into the Collision Hall. The end of the yellow bar shows the schedule contingency. Thus, we see that the Vertex Magnet is scheduled to be installed in the fall shutdown in '06. It is highly likely to be installed by February of '07. This event defines the start of part 2 of the pre-operations phase of this commissioning plan.



4 Commissioning the C0 IR

The C0 Interaction Region has to be commissioned in order produce collisions at high luminosity in C0. This will be done in the first month of operation in December of 2009, after extensive checkout before components are moved to C0 and then after they are installed in the beam enclosures upstream and downstream of the Collision Hall. All the components of the IR are located outside the Collision Hall and therefore do not impact the installation of the BTeV detector.

4.1 Checkout during Installation

Table 1 shows the checkout steps that are performed without beam during the period when the BTeV detector installation is still underway. Two weeks are required for this check out. Single shift operation is assumed.

Activity	**Duration (days)**
The following activities require no beam and can be carried out while installation continues in the C0 Collision Hall.	
Ramp and Squeeze with PS off to test Sequencer, ramps, clock events, abort system; start conditioning ES separators	2
Commission 7 new low beta PS's and 2 new shunts at low current	7
Commission new QPM systems	2
Retrain Tevatron dipoles to 1010 GeV	1
Train new LB quads to 1010 GeV	1
Test new correctors; ramp separators to full voltage; test new collimators; test abort kickers; sign off for beam permit	1
Total	**14**

Table 1: IR Component checkout during the 2009 installation period

4.2 Commissioning with Beam

Once the BTeV Detector work in the Collision Hall is complete, beam can be injected into the Tevatron. The Collision Hall will be secured and commissioning will begin. Commissioning will take place around the clock. The various steps of the plan are shown in Table 2. The full program is expected to take 25 calendar days. At the end of this period, the beam conditions will be stable enough and the luminosity will be adequate to begin detector check.

Activity	**Duration (days)**
At this point beam can be injected. The Collision Hall must now be secured. These activities will be conducted "around the clock".	
Low intensity proton studies:	
Commission 150 GeV: proton injection tune-up; orbit smooth; tune, coupling, chromaticity adjustment on central orbit @ 150 GeV; recommission BPM system; adjust abort timing; lattice measurements and adjustments	3
Commission ramp: orbit smooth; tune, coupling, chromaticity adjustment on the central orbit	2
Commission C0 LB squeeze: orbit smooth; tune, coupling, chromaticity adjustment on the central orbit	2
Commission B0/D0 LB squeeze: orbit smooth; tune, coupling, chromaticity adjustment on central orbit	2
Lattice measurements and adjustments at LB	1
Commission helix at 150 GeV: differential tune, coupling, chromaticity adjustment; reverse proton tune-up for pbar injection	1

Commission helices on ramp: differential tune, coupling, chromaticity adjustment	2
Commission helices on C0 LB squeeze: differential tune, coupling, chromaticity adjustment	2
Commission helices on B0/D0 LB squeeze: differential tune, coupling, chromaticity adjustment	2
Dedicated studies for recommissioning instrumentation and associated software: Synch Light monitor, E17 Schottky, Tevatron Electron Lens, Flying Wires, Fast Bunch Integrator, Sampled Bunch Display, tune meter, dampers, new collimators, Beam Line Tuner, Collision Point Monitors, Ion Profile Monitor	3
Total	**20**
High Intensity Studies	
Proton only store on central orbit, proton helix, and pbar helix; includes additional instrumentation recommissioning; C0 collision helix and B0/D0 collision helix	3
low intensity 36 x 4 store with collisions at C0: cogging scan; separator position and angle bumps; adjust tunes, coupling, chromaticity	1
low intensity 36 x 4 store with collisions at B0/D0: cogging scan; separator position and angle bumps; adjust tunes, coupling chromaticity	1
Total	**5**
At this point, the Tevatron is ready to support collisions at modest luminosity	
Grand Total	**25**

Table 2: C0 IR commissioning activities with beam in the Tevatron

5 Beam “Conditions” for Commissioning

After the initial beam commissioning, BTeV will have control over the beam conditions during the detector commissioning phase. The most frequent operating condition will be “normal collisions” at varying luminosities, with the BTeV Vertex Magnet and the compensating dipoles energized.

Other possible beam conditions used in commissioning include:

- “Magnet off”: proton-antiproton collisions with the Vertex Magnet and compensating dipoles turned off, a special corrector configuration for the IR, Pixel detector retracted, and luminosity kept relatively low. This mode is useful for detector alignment studies.
- Wire target: a wire target is inserted upstream of the IR in the antiproton beam halo. The particles produced are more parallel to the beam than those produced by collisions in the IR. The Vertex Magnet and compensating dipoles may be on or off.

- Single beam: Only proton or antiproton beam in machine, Used to study beam halo and beam- gas interactions
- Sparsely bunched beams: beams with fewer bunches than 36 on 36, for example 36 on 4 or 36 on 1. These are used for a variety of purposes, for example to increase the effective beam crossing interval to check time that detectors are aligned (synchronized) in time.

6 Trigger and DAQ Commissioning and Use in Support of Detector Commissioning

The BTeV trigger and DAQ must be commissioned very rapidly because they are needed to support the commissioning of all the other detector subsystems. The BTeV trigger and DAQ have been designed to support such rapid commissioning.

The approach that BTeV will use to commission the trigger and DAQ systems is to take advantage of the system architecture. Since the architecture consists of eight parallel trigger/DAQ highways that operate independently of each other, we can implement a complete trigger/DAQ highway to facilitate testing of individual components as well as system testing prior to deployment of each production highway at C0. The first complete trigger/DAQ highway is referred to as the *pilot* system, and it will be completed by the end of 2007. Besides serving as a full-fledged test bed for all of the trigger and DAQ components, the pilot system also serves as a reference system for the *production* highways. As each production highway is commissioned, its performance will be analyzed and benchmarked against the pilot system.

The Trigger and DAQ production highways will be used to support commissioning of the BTeV detector, while the hardware and software that will be needed for detector commissioning will be developed and tested using the pilot system. For detector commissioning we will *partition* the trigger/DAQ system to provide independent trigger and DAQ functionality to multiple subsystems in parallel. Initially, there will be a partition for each detector subsystem. This means that each detector subsystem will be able to operate with its own trigger and DAQ independent of any other detector partition. Later in the commissioning process, detector subsystems can be grouped into partitions in any way that is desired. This partitioning will allow detector groups to commission subdetectors independently or in combination with other subdetectors. It will also allow software developers to test new trigger algorithms or work on bugs while commissioning is going on. For example, the pixel and RICH detectors could operate in one partition, the muon detectors in a second, while L3 algorithm programmers are running in a third. Partitioning will be available in increasing levels of complexity during the construction period. At the first level, early on (Summer of 2007) subdetector groups will be able to read data at low rates from their DCBs over the control network. By the end of 2007, the pilot highway will be completed and partitioning will be handled on a highway basis. The complete partitioning functionality will be available by the end of 2008, allowing experimenters to run partitions that collect data from selected components that may span detectors and highways.

Besides providing significant computing resources to support detector commissioning, the trigger and DAQ will also provide diagnostic tools that will be developed as part of the BTeV trigger and DAQ software development. Based on our past experience, the availability of extensive monitoring information provided during the very early stages of detector commissioning contributes to rapid commissioning of the entire experiment. For instance, in the FOCUS experiment we produced a complete "snapshot" of the entire detector performance ranging from high-level diagnostics such as track reconstruction and alignment parameters, primary and secondary vertex distributions, magnetic field variations, reconstructed K_s and Λ particles for diagnostics, and various final physics distributions, such as charm particle mass distributions, to low-level diagnostics for individual subsystems (for example, histograms showing hits in each detector channel) . The high level diagnostics are designed to indicate problems while the low level diagnostics are there to permit drill-down capability to isolate and debug problems. In BTeV, we will have significantly more computing resources available for diagnostics, and will perform many of the calculations that are needed to provide high-level diagnostics as an integral part of the trigger calculations. Besides providing the necessary diagnostic and calibration tools, the trigger and DAQ systems will provide extensive monitoring data to collaborators over the network within seconds or a few minutes (depending on the type of data) to support detector commissioning.

6.1 Trigger Commissioning

The trigger hardware consists of four subsystems: the L1 pixel trigger, L1 muon trigger, the Global Level 1 trigger,GL 1, and the Level 2 and 3, L2/3 trigger. The L1 pixel trigger is the most challenging of the subsystems, and its commissioning will be described in greater detail. The L1 muon trigger uses the same hardware as the L1 pixel trigger, and is approximately one tenth the size of the pixel trigger. GL1 also uses L1 pixel trigger hardware so that we avoid having to develop a unique design for what amounts to a rather small-scale subsystem. The L2/3 trigger hardware consists of commodity PCs running the LINUX operating system, and an Ethernet network to handle data as well as monitoring and control information. Each highway consists of fewer than 100 dual-CPU PCs. Extensive experience with farm systems at Fermilab makes the commissioning of the L2/3 farm a straightforward task. The four trigger subsystems are designed to operate independently of each other for subsystem testing and commissioning.

The L1 pixel trigger is divided into two major subsystems. The first subsystem is the *pixel processor and segment tracker*. It consists of several hundred field programmable gate arrays (FPGAs) for parallel processing of the data. The second subsystem is the *L1 farm*, which has 2500 digital signal processors (DSPs), and is similar to the L2/3 trigger farm in that each processor will complete the calculations for a single beam crossing before moving on to the next beam crossing. Both subsystems include design features to support rapid commissioning, such as built-in diagnostic capabilities and input buffers that accept raw data from the detector during normal operating conditions and Monte Carlo data during commissioning. Monte Carlo data will be used to test all aspects of the trigger system before any hardware is moved to the first floor counting room at C0. The tests on the production hardware will be performed at the Feynman Computing Center. Integration Test Facility (ITF), with many of the tests based on existing test software that has been used for trigger studies since 1999.

Trigger installation sequence at C0:

1) Test trigger components at ITF. The ITF provides an end-to-end test of all trigger and DAQ subsystems for a complete highway, prior to installation at C0. It is used for both development and acceptance testing.
2) Install empty electronics racks.
3) Racks are wired and plumbing is added to provide power and cooling.
4) Install sub-racks and connect to power and cooling.
5) Install trigger modules.
6) Connect and route data and control cables.
7) Repeat system tests as performed at ITF.

In addition to the commissioning that will be performed at ITF and repeated at C0, we will commission the trigger/DAQ using real data and by injecting standard data sets (events with a known trigger response) into the data stream coming from the BTeV detector. This is a powerful methodology that has been used in previous experiments to verify proper operation of trigger and DAQ systems. We will build on upon this methodology by exploiting our highway architecture. The BTeV trigger/DAQ architecture enables more extensive and more and detailed diagnostics for commissioning by comparing the performance of one highway to every other highway.

BTeV's main triggers are derived from the pixel detector and the muon detector. During commissioning, it is possible at times that one or both of these detectors might be unavailable as reliable triggers, for example because people are studying them by varying their operating conditions. We have added a separate trigger path to cover both this contingency and to provide a means of triggering on pulsers for calibrations. We call these "front end primitives" and they are simple logic bits that can be set by scintillation counters or logic done on the front end of detectors. They are "orred" with the pixel and muon Level 1 trigger to form the final Global Level 1 trigger. In addition to their regular use in triggering collection of pulser calibrations, we expect to use these only during commissioning and then only if necessary.

There are actually a variety of triggers that will be available almost immediately when beam arrives:

- Crossing clock trigger prescaled with a Level 2/3 "low bias" trigger. This can be as simple as hit counting on any detector or combination of detectors
- Minimum bias pixel trigger
- Displaced vertex pixel trigger
- Single muon trigger
- Dimuon trigger
- Special triggers using front end primitives – for example asking for a few hits in a small counter hodoscope
- Special Calibration Triggers – pulsers

6.2 DAQ Commissioning

The DAQ electronics consists of two basic hardware components: the Data Combiner Boards (DCB) located in the collision hall, and the Level 1 Buffers (L1B) located in the first floor counting room. There are 48 DCB and 216 L1B sub-racks.

The DAQ software provides Run Control, communication, diagnostics, databases, partitioning and high-level Slow Control functions. It resides on various host computers in the counting and control rooms.

Commissioning of the DAQ is expected to be a very fast process, since all components will have been previously been exercised at the FCC Integration Test Facility (ITF) prior to transfer to C0. The majority of the DAQ commissioning process can be accomplished without dependence on other BTeV subsystems.

DCB installation and commissioning will follow the installation of each detector front-end subsystem and does not require that the remainder of the DAQ system be in place. L1B commissioning will be done by data highway, and requires only that the associated DCBs and optical links are installed.

DAQ installation sequence:

1) Test DAQ components (hardware and software) at ITF. The ITF provides end-to-end test of all DAQ and trigger subsystems for a complete highway, prior to installation at C0. It is used for both development and acceptance testing.
2) Install Control Network, Run Control, Slow Control and Database Hosts in counting room. This provides the infrastructure for all other DAQ components.
3) Install Master Timing Generator (MTG) in counting room. This provides the common 2.5 MHz synchronous beam-crossing clock for all front-end subsystems.
4) Install DCB racks in collision hall.
5) Install DCB sub-racks as detector components arrive. The placement of DCBs is linked to the installation of detector front-end modules, and not to specific DAQ highways.

6) Connect front-end modules to DCBs. At this point the detectors can be controlled and read out at low speed.
7) Install L1B racks in counting room.
8) Install L1B and data network sub-racks to match DCBs.
9) Install optical links to connect DCBs to L1Bs.

DAQ commissioning sequence:

1) Verify connections between front-end electronics and DCBs. Front-end systems can be fully controlled and read out by individual DCBs.
2) Verify optical connections between DCBs and L1Bs using DCB simulated and pseudo-random data generators.
3) Read data from L1Bs (via the Data Network) at maximum rate with arbitrary beam crossing selection. Verify that it matches data from low speed direct DCB readout.
4) Read data from L1Bs with L1 Trigger beam crossing selection.

Since each DCB contains a full timing generator and Ethernet connection, it constitutes a complete low-speed data acquisition system and can be used to read out front-end boards at a rate of a few thousand beam crossings per second/sec. Each DCB also includes simulated data generators for input links and a pseudo-random pattern generator for output optical links. This allows in-situ testing of DCB functionality and bit-error rates.

For commissioning, the front-end can be partitioned at the level of individual DCBs. During normal operation the system can be partitioned at the level of a single DCB sub-rack, which connects to one L1B in each highway. The DCB typically assigns beam crossing data uniformly to each of the eight highways but can be programmed for any distribution over a period of up to 64 turns to allow regular calibration/pattern events, and to compensate for off-line highways or detector resonance bunch-to-bunch luminosity non-uniformity.

The Timing System is initially calibrated to provide a synchronized clock at each DCB sub-rack. As detector front-end boards are installed, the clock phase of individual DCB outputs is adjusted to match front-end cable length and intrinsic delay.

7 Individual Detector Commissioning Plans

7.1 Pixel Detector

7.1.1 Phase 1 Detector and Goals

A pixel telescope, which consists of 8 single-chip pixel detectors, is currently being commissioned with beam at MTEST. A few pixel detectors instrumented with the close-to-final FPIX2 pixel readout chips will be tested before and after irradiation. Goals of the test are to study resolution, charge collection, and efficiency under various operating conditions (threshold setting, sensor bias, angle of incidence, operating temperature) to demonstrate that the design resolution is achieved and to establish the operating conditions for the final detector. A prototype control/monitoring system is in place and operational. A multi-purpose readout chain based on PCI is used in the beam test and this will be used for most of our testing during the production phase.

7.1.2 Phase 2 Detector and Goals

In 2005, we will continue with our beam test program including testing of the FPIX2-instrumented multi-chip modules. We will also build a full-scale pixel half-plane and operate it in a condition close to the final detector (cooling, vacuum etc).

A “10% test” will be the first opportunity for us to operate the pixel detector in a collider mode. The 10% test that will take place in late 2007 and early 2008 may include only a thin wire target with the pixel detector planes mounted in air and at a rather large distance from the beam (of order 2 cm or more). We will use the bunch-crossing clock to establish timing for the readout of the full pixel system and the trigger delay and timing. We will also read out the full pixel detector directly to the DAQ (not necessarily going through the L1 trigger processor, but by reading out the Pixel Data Combiner Boards more directly). This is useful for debugging and understanding the performance of the pixel detector. Since the detector will be placed close to the circulating beams, there are issues such as beam impedance, effect on other collision regions, and possible luminosity losses that need to be studied. For operation of the pixel detector the EMI effect on the pixel detector will be studied as a function of beam intensity and distance between the beam and the detector.

7.1.3 Condition of detector at the time of Installation

Testing is a crucial part of the assembly process. Every component will be first tested before passing on to the next stage of the assembly. The pixel modules will undergo a “burn-in” process after assembly before being installed on the TPG substrates. The assembled pixel half-stations and pixel half-detector will be thoroughly tested both electrically and thermally. After installing of the pixel half-detectors into the pixel vacuum vessel and before transporting the vessel from SIDET to C0, a number of additional tests will be performed. These include:

- Vacuum test – the vessel will be pumped down to check for possible leaks
- Cooling test – Leak tightness and temperature performance will be checked with the vessel under vacuum and the modules fully powered.
- Electrical test – the modules will be powered up to check for continuity
- Readout test – all modules on a half station will be readout simultaneously

- Actuator test – the half detectors will be moved closer and further apart and the read-back sensors calibrated.

  When the pixel detector has passed all these tests, it will be ready for installation.

Sensor Voltage: Range and limits (for both voltage and current) established in bench and beam tests. All modules have been tested with sources, and lasers and will have initial voltage settings.

Threshold Voltage: Range established in bench and beam tests. All modules will be tested with test pulses, sources, lasers and will have initial threshold settings.

Local readout: Cabling to nearby racks of PDCBs. All modules will be read out using the correct length and type of cables by PDCBs prior to installation,

Remote readout: All PDCBs connected to pre-tested serial fiber links.

7.1.4 Description of Commissioning Plan

Following the installation, integration, and testing phase of the pixel detector , the commissioning phase will commence using beam halo, and then colliding beam interactions. The integrity of the control/readout chain of each pixel station will have been checked after installation, and the vacuum, cooling, and other mechanical systems (actuators and positioning sensing system) will also be operational by the time of the commissioning.

The final commissioning of the complete set of thirty stations will initially use low luminosity colliding beams of order 10^{31} increasing to greater than 10^{32} during the commissioning period. For safety reasons the pixel detectors will initially be placed at a distance greater than the nominal 6mm from the beam.

The initial phase of the commissioning will require track reconstruction software at a fairly advanced stage that can find tracks using the pixel system in stand-alone mode. The existing Level 1 pixel trigger software provides much of the needed functionality and can be readily extended to handle this task. A second phase will link the pixel tracks to the silicon-strip and straw detector hits. This phase will be devoted to obtaining the relative survey constants for the pixel/silicon/straw detector planes using combined pixel/silicon/straw tracks found in the initial low intensity runs using the full tracking software. It is not expected that the combined fit constants for the pixel system will vary significantly from the initial pixel alignment fit values.

Since the two halves of the pixel detector have to be retracted before each fill, the alignment between the two halves has to be re-calculated after each fill. In addition, since the beam positions cannot be assumed to be the same after each fill, the beam positions need to be measured before moving the detectors to their final data-taking position. The distance of the beams to the pixel stations can be measured with 10 μm accuracy by analyzing a small sample of minimum bias events. Having done that, we will then move the pixel detectors to their data-taking position.

After we have determined the operating position, we will then proceed to align the two halves of the pixel detector. This in principle requires only the determination of the relative distance between the two halves of the detector. The relative positions of the individual modules within each half-station should not be significantly affected by the global motions of the two halves. Again, we will do a rapid alignment using reconstructed tracks of a small sample of minimum bias events. Alignment of the pixel detector and the forward tracking elements will also be established using minimum bias events.

7.1.5 Interaction with Other Detector Studies

After establishing the alignment constants from the data, the pixel detector can be used for initial checks of the L1 trigger. This commissioning activity is described in a separate section.

7.1.6 Tracking Studies with the Pixel Detector

The performance of the pixel detector needs to be understood. This has to be established during the commissioning run. The parameters of interest include track resolution, impact parameter resolution, vertex position resolution, momentum resolution, and detector efficiencies. Taking a large set of minimum bias events can do this. Various factors that will have an impact on these parameters, such as bias voltage, threshold settings, distance to the beam etc will be studied. However, a general idea of the dependencies will already be known from test beam studies. Long term changes between detector systems due to temperature changes in the hall will also be tracked.

7.1.7 Efficiencies under Varied Operating Conditions

The relative efficiency of each pixel module under differing conditions of magnetic field and beam intensity will be studied over the first days of operation with the object of obtaining efficiency maps for each module. In particular, efficiencies of the modules should be obtained using different magnetic field strengths and polarities and checked to see that no unexpected differences are observed between different polarities or that we see no unexpected dependence of efficiencies on track position. Comparisons with expected hit distribution profiles obtained from the GEANT MC will be generated at this point.

7.1.8 Rate Dependences

Once all of the low beam intensity parameters are established, running for several shifts at higher beam intensity will be performed. All calibration constants and detector efficiencies will be re-measured and checked against their low intensity values. Occupancies as a function of rate will also be studied and documented.

7.1.9 Initial Extraction of Physics "Signals"

One early commissioning objective is to obtain a few physics signals in conjunction with the other detectors (K^o_S decays, J/Ψ in the dimuon spectrum using the muon detector etc.). This will be done in the Level 3 trigger software.

7.1.10 Radiation level monitoring

Thermo-luminescent diodes (TLDs), scintillators and other radiation-monitoring detectors will be mounted on the pixel supports. Initial calibrations may be tied to the charged particle rates through the pixel detectors and the growth of leakage current in the sensors.

7.1.11 Special Triggers required

Minimum bias pixel trigger, test pulse trigger

7.1.12 Special Runs needed for calibration/alignment:

- Low luminosity "magnet off" run

7.1.13 Software for required for Setup and calibration/alignment

- Internal alignment and efficiency package
- Package for Alignment and matching with forward tracker
- Standard monitoring package – verify alignment, resolution, efficiency, check time distributions, and monitor for failed or hot channels

7.2 RICH

The BTeV Ring Imaging Cherenkov (RICH) detector encompasses two detectors sharing the same active volume: a gas radiator RICH using 16-pixel MaPMTs as the photon detector arrays and a liquid radiator RICH using 3-inch PMTs as photo-sensitive elements. The gas radiator RICH is mirror-focused, while the liquid radiator RICH is

proximity focused, namely, the Cherenkov cone expands over the active volume and is reconstructed at the 4 PMT array planes. The front end electronics for these detectors utilizes the same front end ASICs, which provide digital readout. The packaging of the front end electronics is different in the two systems because of the different geometrical constraints.
Phase I involves the full implementation of the gas radiator RICH. In addition, the top PMT plane and the liquid radiator vessel are mounted on the RICH super-structure. Thus at the end of phase I, the gas radiator RICH will be ready to be used in the physics data taking. This detector provides hadron identification up to 70 GeV/c, μ identification up to 17GeV/c and electron identification up to 23 GeV/c. Its performance in K tagging will be improved with the addition of the liquid radiator in stage II, allowing K-p separation below 9.5 GeV/c, corresponding to the K threshold in the gas radiator (C_4F_8O).

In phase II the remaining 3 instrumented PMT arrays are installed and the liquid radiator circulation and monitoring system is completed, thus implementing the second RICH detector component.

We are planning to assemble and test the photosensitive arrays at Syracuse before transferring them to Fermilab. We describe the steps to be undertaken in detail for the MaPMT arrays. A similar procedure will be implemented for the PMT arrays.

The process going from a single detector element to the full array encompasses the following step:

1- plateau and gain scan of groups of MaPMTs. In this stage we can determine the optimum voltage at which to operate the detectors.
2- Functionality test of the front end electronics.
3- Assembly of the MaPMTs and the front end electronics into detector "channels": the building blocks of a detector plane. This unit will be used to optimize the threshold setting of individual channels. This will be done scanning a single-photon light source along the sub-unit active element.

Initial tests of the front end electronics will be performed with test stands employing stand alone software and using the PTA-PMC data acquisition interface developed for the present test beam runs at Fermilab. As the final electronics involves a card (multiplexer card) designed to communicate with the final DAQ data combiner boards, we are planning to switch to a prototype of the final DAQ system as soon as it becomes available.

We are planning to include in our system a set of calibrated single photon sources on locations chosen through ray tracing to implement mirror-photon detector plane calibration.

Our commissioning plan encompasses the following steps:

1- Two test beam runs to validate the overall design of the MaPMT readout structure and the PMT readout structure. The former is in progress and the latter will be implemented in 2005.

2- An optimization of the working point of the devices through calibration runs at Syracuse, using a prototype of the full DAQ system.
3- A quick check of functionality of the arrays upon delivery to the assembly hall in C0 (calibration run with diffused light to check integrity after transportation)
4- The same step repeated in the collision hall upon installation.
5- Final commissioning with tracks

An important issue that we need to address in the gas radiator RICH is the mirror to photon detector array alignment. The details of this process are given elsewhere. The first step is a very careful alignment of the mirror tiles with respect to the MaPMT arrays in the assembly hall. This will be fine tuned in C0 with light sources. The first data runs will be used to implement the alignment of the RICH detector with respect to the tracking system. In stage I, the alignment of the gas radiator RICH will use Cherenkov rings from isolated tracks to finalize the alignment of the photon detector plane with respect to the mirror and with respect to the overall BTeV tracking system. In stage II, the PMT arrays can be aligned with respect to the tracking system using large angle tracks.

The software modules needed to monitor and calibrate the detector are:

1. (Slow control monitoring packages)
   - control and monitor of low-voltages, currents and temperatures.
   -control and monitor of high-voltages, currents and temperatures at the photon detector arrays.
   - recording of atmospheric pressure changes with time (to correct for time variation of refractive index of gaseous radiator)
   - front end electronics monitoring (hot channels, dead channels),
   - (detector array monitoring) single photon efficiency.

2- (alignment):
   -Package for global alignment of RICH with tracking system
   -Package to verify/improve internal alignment of mirror tiles and MAPMTs (gas radiator)
   -Package to verify/improve alignment of PMT arrays (liquid radiator) either internally with the mirror/MAPMT system or externally with tracking system

7.3 EMCAL

7.3.1 Phase 1 Detector and Goals

A 5-by-5 array of crystals and PMT's with conventional PMT bases and CAMAC ADC's were used at Protvino test beam to establish the proof of concept: energy and position resolutions and radiation sensitivities of crystals.

7.3.2 Phase 2 Detector and Goals

In 2005, tests with more final HV distribution system, QIE based front-end electronics and PC-based DAQ system will be carried out at MTEST area to demonstrate that the design resolution is achieved and to establish the operating conditions for the final detector. Software used for these studies should be used to define the "production software" for control, monitoring, diagnosis, and analysis of the electromagnetic calorimeter. In 2007, we will operate a small array of crystals in C0, repeating all the studies of the previous phases.

7.3.3 Condition of Detector at Installation

Each combination of a crystal and a PMT is functional, its sensitivity measured, installed in the support structure and verified in its functionality, again. Optical fibers are deployed, which helps us verify functionality of installed crystal-PMT combinations. Most of the crystals that have been installed before the stage 1 installation shutdown will have been tested with final FEB's and DCB's, and either a PC-based DAQ system or the final DAQ.

7.3.4 Sensor Voltage

The light output of each crystal is measured at the acceptance test using a radioactive source. The gain of each PMT is measured when it is accepted using a standard light source. Based on this information, we make pairs of crystals and PMT's with more uniform signal sensitivities than they would be individually. Further, using the same information, we can establish what high voltages should be used for each pair. Previous experience with CLEO's CsI crystals indicates that the overall sensitivities will be good to 6%. Even if they vary twice as much at 12%, they are still acceptable.

7.3.5 Threshold Voltage

The same acceptance data are useful to set data sparsification seed thresholds properly. In addition, small amount of initial data arising from electron tracks will give us more final calibration data quickly (hours), which allow us to determine better thresholds.

7.3.6 Local readout

PC-based DAQ system combined with prototype FEB's and DCB's will be used to test local readout functions.

7.3.7 Remote readout

Final FEB's and DCB's will be used with a PC-based DAQ or, if available, final DAQ system connected *via* fiber links to test the remote readout.

7.3.8 Description of any special calibration and monitoring hardware

We will use a light pulser system and optical fibers to test and calibrate the sensor elements.

7.3.9 Description of Commissioning Plan

Voltages and electronic thresholds are set before beam is available using our radioactive source measurements of each crystal, electronic pulsing and light pulsing fibers attached to each crystal. We need the beam to align the detector with the tracking system, which will be done using both magnet on and magnet off data, and to get a precise pulse height calibration of each crystal using electrons. These are identified by their unique shower shape initially and checked on RICH identified electrons when the RICH is calibrated.

7.3.10 Special Runs needed for calibration/alignment

- For the final calibration, we need regular run with momentum measured electron sample. With full luminosity, we will need only hours of data to figure out calibration.
- A soon as the tracking devices are commissioned, we will utilize low luminosity "magnet off" runs to understand the alignment of the EMCAL with the tracking devices.

7.3.11 Software for required for Setup and calibration/alignment:

- Alignment with tracking devices.
- Crystal-to-crystal calibration software using momentum-measured electron sample
- Standard monitoring package – verify alignment, energy and position resolutions, efficiency, check pulse height distributions, and monitor for failed or hot channels

7.4 Muon Detector

7.4.1 Phase 1 detector and goals

Ten planks of proportional tubes will be tested in the test beam in August. A plank is 32 proportional tubes arranged in two offset layers of 16. These planks have prototype front-end electronics that use the ASDQ chip that will be used in the final detector. We will measure the speeds and responses of various gases, look for any high rate effects, and measure individual tube efficiencies and resolutions. We will not use the final DCB readout or the final high voltage or low voltage systems.

7.4.2 Phase 2 detector and goals

In FY2005, we will construct 8 pre-production octants to shake down our assembly lines. We will use these pre-production octants in the "slice test" studies planned for MTEST and C0. The C0 tests will allow us to (1) further understand the operating characteristics and parameters of our proportional tube planks, (2) test and debug the alignment, readout, and reconstruction software that we will need for final commissioning, and (3) test the stand-alone di-muon trigger algorithm.

7.4. 3 Condition of Detector at Installation

The basic unit of installation for the muon system is the octant. An octant is a pie-shaped wedge that covers one-eighth of the area covered by one plane of detectors. It is a self-contained unit with a small number of service connections (gas, HV, LV) and readout connections. Prior to installation each octant will undergo a rigorous testing and quality assurance program. We will verify that the octant is gas-tight, that all channels are being read-out properly and are functioning properly, that there are no broken wires or noisy channels. We will also have operated each plank in a cosmic ray test stand and done plateau, threshold, and efficiency studies on each, so we will have a good idea of the operating parameters of each plank.

7.4.4 Sensor Voltage and Threshold Voltage

Threshold and sensor voltage settings are directly related to the noise environment in the Collision Hall. Ideally, the thresholds for the channels will be set so that the noise in the detector from electronic sources in the Collision Hall does not exceed 1% of the expected occupancy due to tracks traversing the detector planes. This is a goal of roughly 100Hz of noise/channel. Since we already know the sensor voltage point and threshold at which a tube is 100% efficient from our testing prior to installation, we will set the threshold and the sensor voltage at the same time in the Collision Hall after installation with beam off. Efficiencies will be verified with beam on.

7.4.5 Local readout

Each octant will have a small number of connections to nearby racks of DCBs. As described above, all modules will have been read out by DCBs prior to installation.

7.4.6 Remote readout

All DCBs will already be connected to pre-tested serial fiber links.

7.4.7 Description of Commissioning Plan

We will need to connect each octant to the experimental hall services (gas, HV, readout) and confirm that these services are functioning properly. We will then proceed with commissioning.

Our commissioning plan consists of final tweaking of our operating parameters for the planks (thresholds and sensor voltages) and of alignment. Alignment will begin with a survey of each wheel of detectors to determine their relative positions and to establish initial positions of each wire in the muon system. We will then use our internal alignment software to refine these positions. For this step we can use wire-target running or beam collisions. These studies need to be done with the muon toroids turned off. We will have tested this software in the slice tests and on Monte Carlo. Once pixel detector data becomes available, we will use tracks reconstructed in the pixel detector to do the final alignment of the muon system (again with magnets off). This procedure is very similar to the one used in the FOCUS experiment to align the PWC tracking chambers.

The stand-alone di-muon trigger will be studied using the stage-1 detector. For Stage 1 of BTeV, we will install the two downstream detector stations (stations 2 and 3). This allows for offline muon identification but does not allow for the Level 1, stand-alone, di-muon trigger. However, we will also install two r-view octants of station 1 which will allow us to completely study the Muon Trigger offline and commission it by replaying real data during the off period for Stage 2 installation so it will be ready when we resume operation. Subsequent installation of station 1 between the two halves of the toriod assembly will provide the full functionality of the system.

7.4.8 Special Runs needed for calibration/alignment

Low luminosity magnet off runs.

7.4.9 Software for required for Setup and calibration/alignment

- Internal alignment and efficiency package

- Package for Alignment and matching with Pixel detector
- Standard monitoring package – verify alignment, resolution, efficiency, check time distributions, and monitor for failed or hot channels

7.5 Forward Straw Tracker

7.5.1 Phase 1

Two 48 straw modules, the lowest level building blocks of the straw system, are currently being tested with beam. Goals of the test are to study various gas mixtures and high voltage combinations to demonstrate that the design resolution is achieved and to establish the operating conditions for the final detector. Rate studies will also be carried out. Readout is via the final front end electronics chip, but not with the final TDC system or data interface (DCB). Similarly, the high voltage and low voltage distribution is only a temporary solution.

7.5.2 Phase 2

In 2005, we will construct a half-station. This half-station will be equipped with prototype electronics, including front-end electronics, high voltage and low voltage distribution, but with external TDCs. Later in 2006, a FPGA prototype of the TDC will be installed into the detector. In addition to validating all aspects of the mechanical design, this system will be read out into a prototype DAQ system as part of the horizontal slice test. At the end of this program, the operating conditions of the straw chambers should be completely determined and the mechanical and electronic design should be validated. Software used for these studies should be used to define the "production software" for control, monitoring, diagnosis, and analysis of the straw detector. In 2007, we will operate the test half-plane with an early version of the ASIC TDC in C0, repeating all the studies of the previous phases.

7.5.3 Condition of the Detector at Installation

The Straw detector is in the following conditions just following installation:

1) All straw channels have been plateaued with HV and threshold voltages set accordingly.
2) All cabling (HV, LV, and signal) will have been checked and verified, both visually and by checks with radioactive sources (by tracking source location to hit patterns in monitoring software).

3) The individual straws with a given station will be known relative to a station fiducial to an accuracy of 100 microns (straw intrinsic resolution is 150 microns).
4) The station fiducials will have been surveyed into place with an accuracy of 1/2 a straw diameter (2mm). This is consistent with the road width used in current track algorithms, and should be sufficient for the next step of using the beam to survey the detector *in situ.*
5) Data from both Cosmic Rays and with calibration pulses will have been taken from the detector front ends through the entire DAQ chain.

7.5.4 Sensor Voltage

Range established in bench and beam tests. All installed modules hold voltage at the upper end of the operating range. All modules have been tested with sources and have initial voltage settings.

7.5.5 Threshold Voltage

Range established in bench and beam tests. All installed modules hold voltage at the upper end of the operating range. All modules have been tested with sources and have initial threshold settings.

7.5.6 Local readout

Cabling to nearby racks of DCBs. All modules have been readout by DCBs into the full DAQ system as part of the installation (1.10) checkout,

7.5.7 Remote readout

All DCBs connected to pre-tested serial fiber links (as part of the Installation subproject (1.10)).

7.5.8 Description of any special calibration and monitoring hardware

The straw ASIC TDC has a built in pulser which is used to calibrate and verify the Front End Electronics. This testing (including readout into the DCB and full DAQ system) will have taken place during the Installation Phase of the Project (1.10). All other monitoring hardware (environmental monitors, gas gain, and HV monitoring will have been checked out during Installation.)

7.5.9 Description of Commissioning Plan

The Straw stations will be preset with the nominal starting HV and Threshold voltages. Data will be taken at low luminosity, to insure that the individual straw occupancies are at a minimum level. Histograms of the TDC spectra will be automatically analyzed to determine timing offsets with respect to the beam crossings, Once we are satisfied that the Straw System is behaving as expected, a low luminosity run "magnet off" run will be used to align the Straw Detector to the "C0" beamline coordinates (and the other BTeV detectors-excluding the Pixel Detector which will be in the "Out" position) .The station mechanical alignment done during the installation period (1.10) will have been done to a level consistent with known multiple scattering angles, so that tracking in this low luminosity "magnet-off" environment will be relatively unambiguous. Once the alignment has been done, the analyzing magnet will be turned on and tracking studies though the field region will begin. Special attention will be paid to the inner stations which are in the magnetic field and whose drifting characteristics may change with the magnetic field on. When the Pixel detector is moved in another low luminosity run will be made to align the entire forward tracking system to the Pixel detector. As the luminosity is increased, we will monitor the Straw detector to look for rate related effects (none are expected at the nominal BTeV running luminosity).

7.5.10 Special Triggers required

A minimum bias trigger

7.5.11 Special Runs needed for calibration/alignment

- Low luminosity "magnet off" run
- Low luminosity "magnet on" run (with Pixels in "In" position).

7.5.12 Software for required for Setup and calibration/alignment

- Internal alignment and efficiency package
- Package for Alignment and matching with Pixel detector
- Package for alignment with forward microstrip tracker
- Standard monitoring package – histogramming package with automated analysis, verify alignment, resolution, efficiency, check time distributions, and monitor for failed or hot channels

7.6 Forward Silicon Tracker

7.6.1 Phase 1

It is currently underway and is essentially devoted to establish the main technological choices of the project. We already tested the performance of the CMS type micro-strip sensors under the radiation-dose profile expected in ten years of operation in BTeV. Any degradation effect in charge-collection efficiency can be reduced to a negligible level by increasing the bias-voltage from the initial 130 V to 350 V, a voltage still far away from the breakdown. We are currently assembling the first prototype of ladder in a quasi-final configuration with the first version (Pass 1) of the readout chips designed for BTeV and successfully tested this spring. The results of the tests on the ladder will validate our design and define all the remaining variables to proceed to the next Phase 2. The DAQ will be the PCI-based version we developed for all the test-phase of the project and will allow for a full characterization of the readout as in the real experimental conditions. These tests should be completed by the end of this year.

7.6.2 Phase 2

Part 1: Dedicated to finalize the ladder configuration and the support structure. It will employ the Pass 2 readout chip (hopefully the final one), the BeO hybrid circuits, the flex cables, the final sensors and all the mechanical support structure with the embedded cooling system. It will allow for a refinement of the details before the production. It will start with the construction of a ladder prototype, then followed by a plane prototype. This phase will last all 2005 and part of 2006. The prototypes will be tested on the bench and on the test beam. We will rely on the same PCI-based version of DAQ used for the Phase 1, and eventually a prototype of the final BTeV DAQ with DCBs to certify the whole detector functionality in the real running conditions. For High and Low Voltages we will use a very flexible CAEN Power Supply System with all the voltages floating, a special feature which will allow us to define the type of grounding that we need. A preliminary version of calibration and alignment software will be developed in this phase and will constitute the seed for the final software development.

Part 2: It will be focused on the final pre-operation test at C0. It will begin in 2007 with the construction of a station with all the pre-production parts and culminate in 2008 with the full horizontal and vertical tests at C0 of two partially assembled stations. The infrastructure for readout & control, power supplies and cooling will be a part of that foreseen for the experiment.

7.6.3 Condition of Detector at Installation

The detectors will be installed once fully characterized and demonstrated to satisfy all the requirements. During the installation and immediately after, before to declare the detectors ready for commissioning, they will be re-checked for possible problems caused by the installation process and then connected to the final BTeV DAQ through the dedicated DCBs.

7.6.4 Sensor Voltage

Initial Bias voltages to apply to the sensors will be available in a Data-Base containing all the characteristics of each sensor, which were measured during the acceptance tests. They are expected to change during the run because of the radiation damage and will be updated by continuously monitoring the evolution of the detector performance.

7.6.5 Threshold Voltage:

Similarly, the initial Threshold voltages will be read from the detector Data-Base, containing all the characteristics of each ladder, which were measured during the ladder construction process. They may vary during the run and, in case, can be updated by continuously monitoring the evolution of the detector performance.

7.6.6 Local readout

Cabling to nearby racks of DCBs. All modules have been readout by DCBs prior to installation,

7.6.7 Remote readout

All DCBs connected to pre-tested serial fiber links.

7.6.8 Description of any special calibration and monitoring hardware

None. All the hardware required for electronic calibration is already integrated in the readout chips.

7.6.9 Description of Commissioning Plan

Commissioning the micro-strip system essentially means to verify the functionality of the readout in the real experimental conditions, to establish the alignment of the detectors and to validate the pre-loaded electronic calibrations with particles. We will execute these operations in sequence. Once established the correctness of the data collected by DAQ, we will proceed to the alignment. Alignment will consist of two phases, the internal alignment of the micro-strip planes and their relative alignment with respect to the other tracking detectors, i.e. the pixel and the straw system. Both will be established by running at low luminosity with magnet off. The same run will allow us to calibrate the detectors with particles by reconstructing the MIP peak on the pulse-height histograms accumulated for each strip. It is worth noting that, analogously with what we did for pixels, we have recently decided to add 3 bits of analog information in the micro-strip readout chip too. This will make the control and monitor of the system much easier during all the duration of the experiment.

7.6.10Special Runs needed for calibration/alignment

- Low luminosity "magnet off" run

7.6.12 Software required for Setup and calibration/alignment

- Internal alignment and efficiency package
- Package for alignment and matching with pixel detector
- Package for alignment with straw tracker
- Standard monitoring package – verify alignment, resolution, efficiency, and monitor for failed or hot channels

8 Strawman Overall Final Commissioning Plan

The commissioning of the BTeV IR, based on the plan presented in section 4, is expected to take about 1 month. Even though beam could be available for at least some parasitic commissioning on spray or interactions towards the end of this period, we do not consider this in our plan. We plan the commissioning as a succession of tasks using collisions and measured in "store-shifts" following the month of IR commissioning.

During the commissioning period, BTeV will be the only experiment running at the Tevatron and will therefore be able, by agreement with the Accelerator Operations Department, to have substantial control over the schedule of colliding beams and access periods.

In all cases, there will be a "principal" activity or goal for each shift and a person responsible for that activity will have control of the configuration of the apparatus, including the trigger and DAQ, and the beam conditions. However, the BTeV trigger and DAQ are highly partitionable so they can in provide a very large number of independent

Data Acquisition systems each with their own independent trigger and run control. A special ancillary trigger system, called the "front end primitive" system provides simple triggers for startup and calibration and can be used to set up special triggers for each detector, if desirable. Therefore, several activities should be able to run parasitically to the principal task of each shift. This should facilitate commissioning. However, too many parallel activities can lead to chaos, so the shift coordinator maintains control over the parasitic commissioning activities on his/her shift. Detailed shift plans will be written in advance and will state the work to be done, the beam and detector requirements, and the trigger conditions.

In the following, we assume about 2/3 "uptime". There is a 1 day period each week for accesses to fix equipment. We also provide time for beam studies and tuning. This will obviously be scheduled at the most opportune time and may be distributed. Short accesses can be taken between stores.

8.1 week 1

Major goals for this week are time alignment and checkout of each detector on interactions and commissioning of the tracking system – pixels, forward microstrip tracker, and the forward straw tracker. These systems are needed to provide tracks for commissioning the other detectors.

8.1.1 Shifts 1-6

Six shifts of study of time alignment and verification of detector channel health at low luminosity. We use a beam of 1 on 36 bunches. Each detector is triggered on either 1) a prescaled crossing clock trigger 2) a front end primitive (FEP) implemented interaction trigger, or 3) a dedicated FEP trigger. The goal is to verify that each detector's data get the proper time stamp and to demonstrate that nothing is close to a timing edge. Data from each detector will also be checked for dead, hot, or weak readout channels.

8.1.2 Shifts 7-9

Possible 3 shift access to repair problems.

8.1.3 Shifts 10-15

Six shifts of pixel detector studies: These will be low luminosity, 10^{31}, 36 on 36 bunch runs with a crossing clock or FEP implemented interaction trigger. The pixel detector will be moved in to about 1.2 cm from the beams. Runs will be taken with magnets on and magnets off for alignment purposes. The rapid alignment software will be used to establish the position with respect to the beam. Various operating conditions for the pixel detector can be studied.

Some parasitic data collection for the other detectors is likely to occur during these shifts.

8.1.3 Shifts 16-18

Three shifts of silicon strip studies: These will be low luminosity, 10^{31}, 36 on 36 bunch, runs with a crossing clock or FEP implemented interaction trigger. The goal will be to collect data for the alignment of the detector and to study the detector performance under varying conditions. It will include both magnet off and magnet on runs. The pixel detector will be available and in a stable operating mode for readout for this period.

Some parasitic running for the other detectors can occur during these shifts.

8.1.4 Shifts 19-21

Three shifts of straw studies: These will be low luminosity, 10^{31}, 36 on 36 bunch, runs with a crossing clock or FEP implemented interaction trigger. The goal will be to collect data for the alignment of the detector and to study the detector performance under varying conditions. It will include both magnet off and magnet on runs. The pixel detector and the silicon strip detector will be available and in a stable operating mode this period

Some parasitic running for the other detectors can occur during these shifts.

8.2. Week 2

At this point, we will have a functioning tracking system, although the pixel detector may be operating farther from the beam than the final goal of 6 mm. Goals for the second week are to commission the RICH, EMCAL, and Muon detectors and the pixel detached vertex trigger.
8.2.1 Shifts 22-30**Three shifts each for EMCAL, Muon, and RICH:** These will be low luminosity, 10^{31}, 36 on 36 bunch, runs with a crossing clock or FEP implemented interaction trigger. The goal will be to collect data for the alignment of each detector and to study the detector performance under varying conditions. It will include both magnet

off and magnet on runs. The pixel detector, the silicon strip detector and the straw detector will be stable and available for readout throughout this period

8.2.2 Shifts 31-33

Three shifts Pixel positioning study: These will be low luminosity, 10^{31}, 36 on 36 bunch, runs with a crossing clock or FEP implemented interaction trigger. The Vertex Magnet will be on. The goal will be to verify that we can position the pixel detector safely with respect to the beam, that we can quickly reestablish the alignment, and determine where the beam is, and that we understand the radiation levels at the detector.

8.2.3 Shifts 34-36

Three shifts of IR tuning, if required: Parasitic operation of some detectors may be possible. Pixel detector will be in retracted position

8.2.4 Shifts 37-39

Three shifts for checkout of the Pixel trigger: It is done by using a crossing clock trigger or interaction trigger and recording a pre-scaled sample of all events. The trigger just marks whether the crossing would have been accepted or not. The offline analysis running on the pixel data will verify the trigger decisions. We already have all the software required to do this. These will be low luminosity, 10^{31}, 36 on 36 bunch, runs with a crossing clock or FEP implemented interaction trigger. The Vertex Magnet will be on. The pixel detector will be located 6mm from the beam.

8.2.5 Shifts 40-42

Possible 3 shift access to work on equipment.

8.3 Week 3

By this time, all detectors have been commissioned and have preliminary alignments based on the data taken in the previous week. The Pixel trigger has been commissioned at low luminosity.

8.3.1 Shifts 43-45

Three shifts of tracking detector final studies: These shifts are available if there are any additional issues that need to be resolved on the tracking system.

8.3.2 Shifts 46-48

Three shifts of EMCAL, RICH, and Muon studies: These shifts are available if there are any additional issues that need to be resolved on these systems.

8.3.3 Shifts 49-51

Three shifts of muon trigger studies: These shifts are available for checkout of the muon trigger

8.3.4 Shifts 52-54

Possible three shift access to repair any detector or electronics problems.

8.3.5 Shifts 55-63

Nine shifts of "physics" Runs at 10^{31}: This uses the pixel trigger for minimum bias events (prescaled), detached vertex events, and the muon trigger, and is a full detector and trigger checkout at low luminosity. It should establish a baseline for rate studies that will follow.

8.4 Week 4

At this point, all detectors and triggers have been commissioned and the system is capable of taking physics quality data at low luminosity. The goal for this week is to raise the luminosity and see how the detectors and trigger behave and make whatever adjustments are necessary to operate efficiently at the higher luminosities. At the start of this week, the luminosity is raised to 5x$\mathbf{10^{31}}$**.**

8.4.1 Shifts 64-66

Three shifts of IR tuning to prepare for luminosity increases

8.4.2 Shifts 67-69

Three shifts of pixel alignment studies at $5x10^{31}$: This is to establish the relative position of the beam and the pixel detector and to position the pixel detector at the nominal 6mm distance from the beam.

8.4.3 Shifts 70-78

Nine shifts of physics runs at $5x10^{31}$: The purpose is to compare the detector and trigger performance at this luminosity with the low luminosity baseline,

8.4.4 Shifts 79-81

Three shifts of IR tuning if needed to go to 10^{32}.

8.4.5 Shifts 82-84

Possible three shift access to repair any detector or electronics problems.

8.5 week 5

BTeV is now taking quality physics data at **$5x10^{31}$.** The major goal of this week is a final rate scan up to **$2x10^{32}$. This will permit us to compare the baseline low luminosity performance with performance at higher luminosity and establish the optimal trigger configuration at each luminosity.** When that is complete, physics data-taking will already have been done.

8.5.1 Shifts 85-90

Six shifts of Data taking at $1.0x10^{32}$

8.5.2 Shifts 91-96

Six shifts of Data taking at $1.5x10^{32}$

8.5.3 Shifts 97-102

Six shifts of data taking at $2.0x10^{32}$

At this point, the commissioning period is over and BTeV will be able to take data at luminosities up to $2.0x10^{32}$, with optimal operating and trigger conditions.